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REVISED BENEFITS FOR LOW-FLOW AUGMENTATION IN THE GRAND (NEOSHO) AND COTTONWOOD RIVER

Public Health Service
Dallas, Texas

August 1960

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REVISED BENEFITS FOR LOW-FLOW AUGMENTATION IN THE GRAND (NEOSHO) AND COTTONWOOD RIVERS

Supplementary to Grand (Neosho) River Investigation,

August 1940 (Revised 1952)

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DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Region VII
Dallas, Texas

In Cooperation with the

DEPARTMENT OF THE ARMY
U. S. Army Engineer District - Tulsa, Oklahoma

AUGUST 1960

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INTRODUCTION

General

In 1940 the Public Health Service made "A study of public water supply and stream pollution in the Grand (Neosho) River Basin and the need and justification for low-flow regulation from conservation storage in proposed flood control reservoirs". The study was made, and a report written, at the request of the Chief of Engineers, United States Army.

A supplementary statement to the 1940 report was prepared in 1952, at the request of the District Engineer, Corps of Engineers, Tulsa District.

Presented herein are the findings of a recent review of the subject, as requested by the District Engineer (Tulsa) by letter dated 10 April 1959, and subsequent correspondence. Benefits were requested for maintaining low-flow control of 10 cfs on the Grand (Neosho) River at Emporia; 40 cfs on the Cottonwood River at Emporia; and 30 cfs on the Grand (Neosho) River at Chanute. These flow rates were recommended by the Public Health Service in 1952.

In a letter dated 20 May 1960, the Deputy District Engineer, Corps of Engineers, Tulsa, advised that their latest hydrologic studies indicate that the 40 cfs minimum flow for the Cottonwood River at Emporia probably cannot be obtained from the authorized

Marion and Cedar Point Reservoirs. Nevertheless, that letter repeated the previous request that monetary benefits be stated for maintaining 40 cfs on the Cottonwood at Emporia. In addition, it has been requested that the statement of benefits be broken down to show separate values for 10 cfs on the Grand (Neosho) River at Emporia; 17 cfs (as well as 40 cfs) on the Cottonwood at Emporia; and 38 cfs released from the John Redmond Dam. The latter figure (38 cfs) is the Corps' latest estimate of the firm yield from the authorized John Redmond storage.

Acknowledgments

The assistance of the Kansas State Water Resources Board and the Kansas State Board of Health is gratefully acknowledged.

SUMMARY AND CONCLUSIONS

Summary

1. This is a review of previous reports, and a re-evaluation of the function of storage for low-flow augmentation, on the Grand (Neosho) River system in Kansas.

2. Communities and industry in the Neosho valley must depend on the river system, both for water supply and for the ultimate disposal of waste products. Ground water resources are meager. For the towns located along the main stem of the river, some re-use of water is inevitable, and the two functions, water supply and treated-waste dispersal, are inseparable.

3. The average annual runoff from the watershed, of over a thousand cfs, is more than adequate to meet expected needs. However, stream flow rates are highly variable, and periods of zero flow for several months' duration occur during drouths. For this reason, storage regulation is needed to provide assured continuous supply.

4. The provision of storage to assure minimum flows at Emporia, Kansas, of 10 cfs on the Neosho River

and 40 cfs on the Cottonwood (or any combination of flows totalling 50 cfs past Emporia), would support a conservatively estimated future growth pattern in the valley for the next 50 years.

5. The most efficient utilization of storage potential will result from consideration of the need for seasonal variation in release rates. Experience is the best guide for establishing operating rules, and further study of this problem is indicated. For the purpose of this study, the following pattern of releases has been assumed. Considering the 50 cfs rate at Emporia to be the average release during a critical dry year, seasonal rates might be:

   150 per cent of average for the 3-month summer period

   85 - 95 per cent of average for a 3-month period

   75 - 85 per cent of average for a 6-month period

6. The approximate nature of the calculations on which stream quality conclusions rest, and the possibility that unanticipated growth may occur, make it desirable to keep the maximum possible flexibility in the master plan for the river. The proposed yields studied herein represent only a small proportion of the potentially available water resource. The door should be left open for greater utilization, as and when the need arises.

Conclusions

1. There is a definite need for providing storage in reservoirs of the Grand (Neosho) River system for low-flow augmentation. Such storage would serve the dual and inseparable functions of water supply and final disposal of treated wastes.

2. Based on the application of the alternative cost doctrine, it is considered that the value of such storage to provide the recommended flows at all points will aggregate $688,000 per year. This figure represents the gross annual benefit, and might be pro-rated as follows:

Location	Full Plan		Curtailed Plan	
	Firm Flow (cfs)	Annual Benefits	Firm Flow (cfs)	Annual Benefits
Neosho River at Emporia, Kansas	10	$137,600	10	$137,600
Cottonwood River at Emporia	40	550,400	17	233,900
Neosho River below John Redmond Dam	38	none	38	151,400
		$688,000		$522,900

3. The construction of projects with a combined yield from storage of only 27 cfs at Emporia (Curtailed Plan) would only defer for a few years the time when additional measures would be required. A higher firm flow rate would be desirable, not only to assimilate

properly the treated waste effluent of an enlarged city of Emporia, but to prevent impairment of the uses of John Redmond Lake. Every possible means should be explored to achieve the objective of assuring combined flows on the order of 50 cfs.

DESCRIPTION OF THE AREA

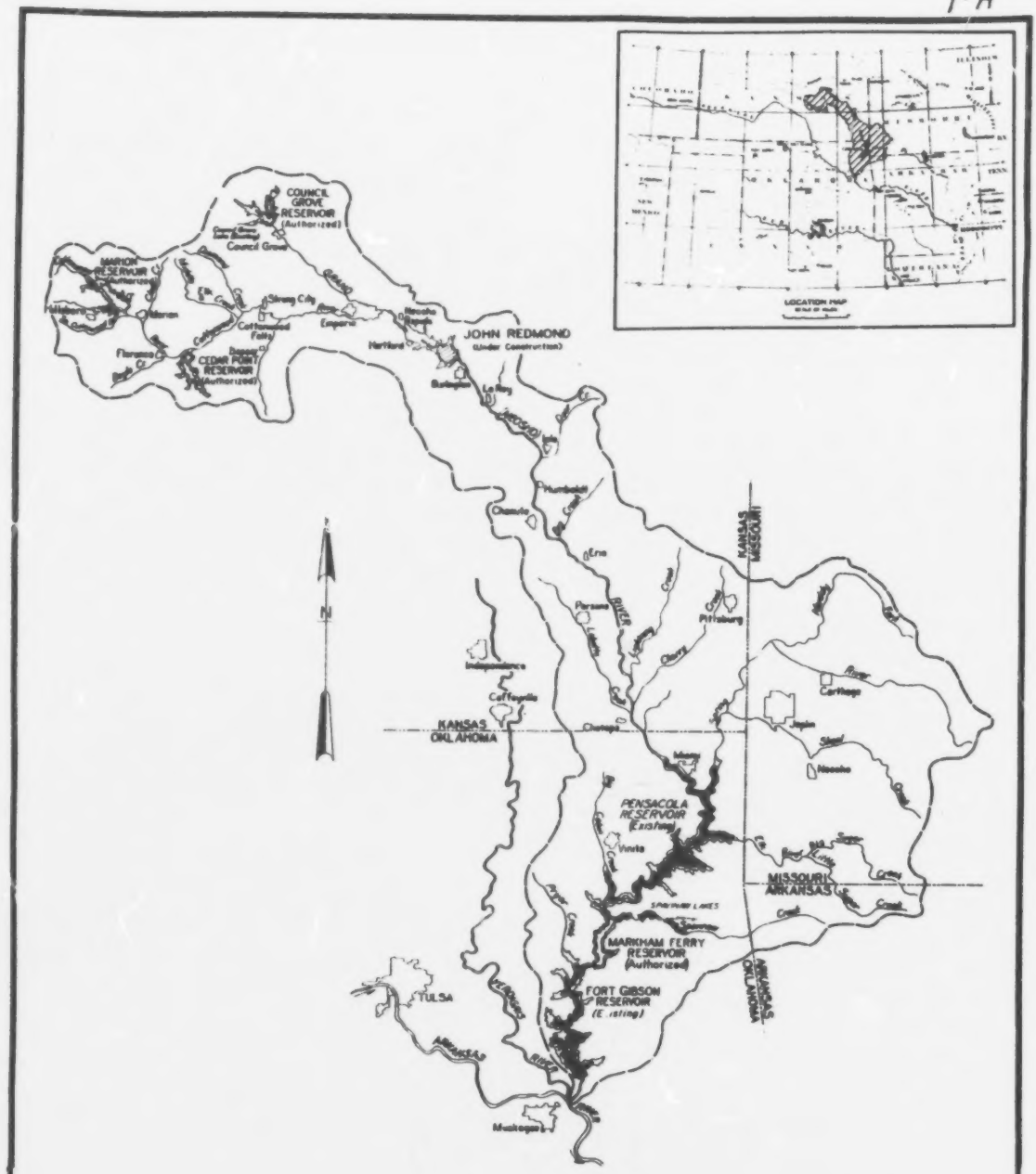
Geography

The Grand (Neosho) River originates in Morris County in east central Kansas and flows southeasterly in Kansas, and southerly across eastern Oklahoma, to its junction with the Arkansas River in Oklahoma. It is known as the Grand River from the mouth to the confluence of Spring Creek, and as the Neosho River above that point. Map No. 1 shows the watershed and its relative location.

Most of the Oklahoma portion of the river is a succession of lakes created by existing dams.

This study is concerned with that part of the main-river watershed lying north of the Kansas-Oklahoma state line. Focal points of the problem are the two largest cities, Emporia and Chanute. Secondary attention must be given to the significant needs for water supply, and effects of waste disposal, of other towns from Council Grove (north of Emporia) to Chetopa, near the state line. Table 1 lists the towns, in the order of their locations down the stream.

From the mouth of the Cottonwood River, downstream for 200 miles, the valley is narrow, and no sizable tributaries enter the stream. Average slope of the channel, between Emporia and the state line, is about 1.4 feet per mile. The river bed consists of gravel, boulders, and ledge rock, and is generally stable. At low flows the channel is a succession of pools and shoals.



GRAND (NEOSHO) RIVER WATERSHED

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE

PUBLIC HEALTH SERVICE

REGION VII DALLAS, TEXAS

MAP 1

Table 1

Populations, Water Requirements, and Waste Loads
Neosho River, Kansas

Town	1950 Population	Projected For The Year 2015			
		Population	M & I ** Water Requirem't (mgd)	Untreated Waste Load (P.E.)*	Waste Load to Stream (P.E.)
Council Grove	2,722	5,200	1.0	6,000	600
Emporia	15,669	31,400	7.9	42,000	4,200
Burlington	2,304	3,940	0.79	5,010	501
Leroy	695	670	0.13	790	79
Iola	7,094	12,800	3.20	17,300	1,730
Humboldt	2,308	4,380	0.88	5,420	542
Chanute	10,109	19,800	4.95	29,500	2,950
Erie	1,296	2,540	0.51	6,540	654
St. Paul	783	750	0.15	1,000	100
Oswego	1,997	4,000	0.80	4,870	487
Chetopa	1,671	2,840	0.57	3,460	346
Totals	46,648	88,320	20.88		

* Population Equivalent. One P.E. assumed equal to 0.25 pounds per day of (ultimate) B.O.D.

** Municipal and Industrial.

Hydrology

The normal annual precipitation over the Kansas portion of the watershed is about 37 inches. On the average, the heaviest rainfall occurs during the spring and summer months, and the lightest during the winter months. This is a fortunate circumstance for water resource utilization. However, wide departures from the average are also characteristic to the area, and critical problems arise during prolonged drouth periods.

Runoff from the watershed is, like the rainfall, highly erratic. At Iola, Kansas, average stream flow has been estimated at 1160 cfs. The need for storage regulation to improve the temporal distribution of runoff is pointed up by the records of past experience. At Council Grove, near the headwaters, periods of zero flow have been frequent, the longest being for a duration of 10 months and 17 days. During the drouth of 1952-57, "the city of Chanute was intermittently plagued by water shortages".[8/] The shortage became so acute that the city resorted to the drastic expedient of recycling its sewage effluent from October 14, 1956, to March 14, 1957.

Water Supply and Waste Disposal

To each town in the study area, the main stem of the Neosho is a natural conduit which brings its water supply and also carries away its final waste waters. Ground water supplies in this reach

of the river are meager. The absence of major tributaries in the narrow valley precludes the impoundment of off-channel water supplies.

Some cities have built low dams across the river channel for local impoundment. Inadequacy of these storage works to meet the needs has been demonstrated during drouth periods. They are vulnerable to damage by the major floods which are also characteristic of the river. It is to be expected that their useful life would be greatly shortened by siltation.

FUTURE GROWTH AND WATER REQUIREMENTS

Present Development

The Neosho valley is sparsely settled, with no large cities or industrial centers in the portion under study. Emporia, the largest city in the area, had a 1950 population of 15,669. In 1957, it was estimated that Emporia's sewerage system was serving a population of 15,800. Other cities of significant size are Chanute (1950 population, 10,109) and Iola (1950 population, 7,094). A total 1950 municipal population of some 47,000 people resided in the eleven towns along the main stream. Distribution is shown in Table 1.

In terms of the number of people employed, agriculture and stock raising are the principal occupations. Stock raising predominates in the headwater region. Oil and gas fields in the vicinity of Iola have produced for many years, but are now largely depleted.

Per capita water use records show a wide variation, typical figures ranging from about 80 to 120 gallons per day. This is well below the statewide average of 155 gallons per day. As a base for future projection, these records are of questionable reliability on two counts--the accuracy of measurements of pumpage and estimates of population served, and the probability that demand has been suppressed by restrictions on use due to inadequate supply.

Future Projection

A report entitled, "Low-Flow Augmentation Requirements, John Redmond Reservoir, Neosho River, Kansas", was jointly prepared in February, 1960, by the Water Resources Board and the Board of Health of the State of Kansas. Concurring with the viewpoint expressed, the following is quoted from that report:

> "Population growth in the Neosho Basin has undoubtedly been deterred by the unstable natural water condition of extreme flood and drouth. However, many items besides water influence the economic growth of a region or community. Thus, the hypothesis that stabilized river flows and partial reduction of the flood threat would lead to growth rates as found in the well watered areas of the nation was discarded. Instead, it was assumed that growth in each community would take place at the average rate experienced for all Kansas communities of that size bracket. These assumptions may be restated as follows: (a) Water has not to date been the predominant factor in establishing the growth rate of Kansas communities, and (b) Statewide experience is the best measure of the other economic and resource factors that influence the over-all growth pattern. This approach probably tends to minimize future water requirements in light of current estimates of over-all national population growth. However, it would appear to assure a realistic appraisal of minimum future requirements. Projections were thus made for the 50-year period beginning with 1965, the assumed date of project completion."

The abovementioned report did not include the cities of Emporia and Council Grove. Projections for these cities were made by this office, using growth rates comparable to those used by Kansas Water Resources Board for the other cities. Project populations at the year 2015 of the eleven municipalities in the study area are given in Table 1.

Projected water requirements for the year 2015 are based on the assumption of rates of 250 gallons per capita day (gpcd) for the three largest cities, and 200 gpcd for the other towns. These rates are intended to include both municipal and industrial requirements, the larger rate reflecting the assumption of a greater concentration of industry in the large cities.

M. & I. Water Supply Requirements

The projected average annual municipal and industrial requirements by the year 2015 total 20.88 mgd for the eleven towns.

Stream Quality Maintenance Requirements

From Council Grove in the north to Chetopa at the southern end of the reach is a distance of some 270 river miles. Aside from other considerations, distance alone rules out the possibility of artificial conduits for water supply. Therefore, it seems certain that the natural river channel will continue to play the same dual role in the future that it has in the past. Each community may be expected to continue to draw its water from the river for municipal and industrial requirements, and to return to the river a portion of that water as waste flow.

This points up a situation which is a common occurrence, although not so commonly recognized. Some portion of the water which is drawn from the river by a downstream city will already have been

used one or more times by its upstream neighbors. This reuse of water (after proper treatment) is acceptable from a public health standpoint, provided appropriate protective measures are taken. These measures include: (1) close surveillance by local regulatory bodies to insure that all wastes are properly treated before their discharge to the stream; and (2) the assurance of minimum stream flow rates sufficiently high to assimilate and dilute the waste products remaining after treatment.

PLAN FOR MEETING WATER REQUIREMENTS

Proposed Storage Reservoirs

The Corps of Engineers plan for the Neosho River system envisions four multiple-purpose dams. Two of these locations are on the Neosho--the John Redmond Dam between Burlington and Emporia, and Council Grove Dam, north of Council Grove, Kansas. The other two, Marion and Cedar Point, are on the headwaters of the Cottonwood River.

As the question has been posed to the Public Health Service, the Corps is studying plans to provide conservation storage in such combinations as to assure a firm yield of 50 cfs (32.4 mgd) at the confluence of the Cottonwood and the Neosho at Emporia, and 38 cfs below the John Redmond Dam. However, it is understood that their latest calculations indicate that the combined firm flow at Emporia will be only 27 (instead of 50) cfs, from the upstream projects currently authorized.

Adequacy of Proposed Flow Rates

Calculations have been made of the effects of organic waste loadings on the quality of water in the stream, at critical points and for the average and seasonal extremes reflected by differences in water temperature. This investigation was made for the hypothetical pattern of water use, return flow, and waste loadings projected for the year 2015.

Specifically, the investigation was aimed at determining whether the given yields from storage would maintain the dissolved oxygen content of the stream at a level of 5 ppm, at all points and at all times. It was assumed that, before the year 2015, the design and operation of conventional sewage treatment plants would be such as to remove 90 per cent of the biochemical oxygen demand (BOD). The remaining 10 per cent was therefore assumed to be the BOD introduced into the river. A statement of the further assumptions made, and an outline of calculation procedures, is given in Appendix A.

The results of the investigation are summarized as follows. The provision of average annual flows, during a critical drouth year, of 50 cfs at Emporia, will keep the dissolved oxygen content of the stream slightly above the 5.0 ppm limit, subject to the following conditions:

1. That storage releases will be able to provide flow rates on the order of 1 1/2 times the average, throughout the three hottest summer months (say, from the middle of June to the middle of September). Calculations indicate that such a withdrawal can be compensated for by reducing wintertime release rates below the average sufficiently to replenish the depleted storage, without impairment of stream quality.

2. That the geographical distribution of waste loadings be substantially similar to the pattern given in

Table 1. Appreciable increase in the waste loading at any one or more points, due to unanticipated growth or special industry, would call for the provision of additional conservation storage.

Particularly with regard to waste disposal, Emporia is the focal point of the valley's problem. This is true not only because it is the largest city of the group, but because of its location at the upstream end of John Redmond reservoir. Failure to provide minimum flows which would adequately assimilate Emporia's wastes could produce conditions in the reservoir which would be esthetically undesirable, a danger to aquatic life, and an impairment to recreational uses.

On the other hand, if a revised plan can be developed which will assure the 50 cfs flow past Emporia, this would solve the problem, not only for Emporia, but for downstream communities. For this reason, in the subsequent discussion of suggested allocation of benefits, no monetary value has been assigned to storage at the John Redmond site under the "Full Plan". Nevertheless, the re-regulation afforded by John Redmond dam would be advantageous in giving more positive control of water dispatched for downstream needs.

If the firm flow at Emporia is limited to 27 cfs (the estimated yield from the projects as currently authorized), it is highly probable that additional measures would be required in the near future

to maintain satisfactory stream conditions. It is estimated that flows of this magnitude would meet the water supply and pollution control needs for Emporia at its present size, and until it grows to about one-and-one-third times that size. That is, 27 cfs would support an Emporia population of about 21,000 persons, with corresponding waste loadings, provided treatment facilities removed 90 per cent of the BOD.

Need For A Flexible Plan

The conditions imposed above, and consideration of the approximate nature of the calculations on which stream quality conclusions rest, call attention to the desirability of keeping the maximum possible flexibility in the master plan for the river. The proposed yields studied herein represent only a small proportion of the potentially available water resource. The door should be left open for greater utilization, as and when the need arises.

VALUE OF STORAGE

The 1940 Report

The following abbreviated quotation, from the 1940 report by Public Health Service on this subject, is equally pertinent today.

"Low flow augmentation by the installation and operation of conservation storage...is extremely desirable and would be of definite benefit to a well balanced water use program for the basin. Outstanding among the beneficial effects...are:"

"(a) Assured quantity of improved quality water for municipal and industrial needs.

(b) Maintenance of satisfactory oxygen relations by providing adequate dilutions for properly treated organic wastes.

(c) Providing a suitable habitat for aquatic life by assurance of minimum flows and prevention of serious oxygen depletions in critical zones of depression."

Monetary evaluation of storage in the 1940 report was calculated in two parts: (1) "Tangible Public Water Supply Benefits", and (2) "Organic Pollution Abatement Benefits". For the first of these (water supply benefits), value was based on the alternative cost of constructing single-purpose impounding reservoirs which might be built in the absence of the Corps projects, to duplicate the yields.

Monetary benefits for pollution abatement were arrived at by estimating the cost of "...necessary supplemental treatment, as tertiary units, that would produce stable effluents."

The 1952 Report

In 1952, the Public Health Service was asked to review the previous findings in the light of changed conditions (just as the current report stems from a request for review in terms of 1960 conditions).

Perhaps the best way to summarize the changes in conditions and viewpoint between 1952 and 1960 is by quoting excerpts from the 1952 report, followed by a statement of present viewpoint.

From the 1952 report:

"Water Supplies

"A review of water supply projects used as a basis for calculating tangible monetary benefits in the original report indicates that conditions have changed materially since 1940. Data from the Kansas State Board of Health shows that a water storage project for Council Grove has been built and the need for a pipeline at Emporia has been satisfied. The need for channel dams for five municipalities is questionable in the opinion of the State engineers.

"It appears, therefore, that any tangible monetary benefits to public water supplies are non-existent."

Present viewpoint:

The experiences of the drouth years culminating in 1956-57 have re-established and confirmed the need for water supply storage.

From the 1952 report

"Pollution Abatement

"Pollution abatement benefits as estimated in the original report (1940) were based on providing intermittent sand filters, following secondary treatment...". "The basis for such projects was justified originally, but present state policy does not require this added degree of treatment. Consequently, tangible monetary benefits..., cannot be justified from a practicable standpoint."

Present viewpoint:

In addition to requiring secondary treatment of all wastes, the Kansas State Board of Health has now established the objective of maintaining the highest practicable level of dissolved oxygen content in all streams, with a minimum of five ppm. The maintenance of this

standard in the Neosho will require supplemental water for assimilation of treated waste effluents.

Among other conditions which have changed, and are changing today, may be cited: (1) a growing public awareness of the dangers to public health in not maintaining stream quality standards; (2) unwillingness to accept the nuisances of polluted streams (or conversely, public willingness to pay the cost of avoidance); and (3) the tremendous increase in the use of chemical products whose wastes are not effectively removed by conventional treatment. The latter include such things as the synthetic detergents, and the wholesale spraying of insecticides and herbicides.

Notwithstanding the above, the 1952 report called attention to numerous intangible benefits of flow augmentation, and recommended the provision of conservation storage to assure yields substantially the same as are recommended herein.

Monetary Value of Storage

For water supply, it is believed that the conclusion reached in the 1940 report has been reaffirmed by recent experience. The value of storage for water supply is considered to be equal to the cost of the most economical alternative method of assuring the same supply, in the absence of Federal projects.

For waste disposal, consideration was first given to possible alternative methods of solving the problem without supplemental water. The two methods which appeared to offer the best possibilities were, (1) stabilization ponds to effect a further reduction of B.O.D. before the effluent was returned to the stream, and (2) holding basins.

The holding basin, in this case, is a variation of the upland storage reservoir for water supply storage, which has been so successfully used in Ohio.[9/] These would be storage basins, located at each town, kept empty normally, into which the waste effluent from the treatment plant would be pumped during periods of low flow, to be released when stream flow was again high enough for assimilation.

Although these alternatives are considered to have possibilities, they have been ruled out for the conditions existing on the Neosho. For one thing, the cumulative return flows from upstream towns add appreciably to the quantity of water at downstream points, and withholding them in times of critical shortage would mean a lesser utilization of available water. Also, upstream storage would still be required for water supply, and it is estimated that the added cost of providing additional storage for dilution water would not be greater than the total costs of building, fencing, and operating a system of local supplementary ponds or basins.

Finally, the disposal of wastes containing such known chemical constituents as are found in certain detergents and insecticides,

and unknown future chemicals, presents a problem for which there appears to be no satisfactory substitute for dilution water.

In the absence of storage in the proposed Federal projects, the best and most economical solution to the complex overall problems under consideration, is considered to be the construction of one or more reservoirs for the purpose of low-flow augmentation, located somewhere upstream for Emporia. These alternative reservoirs would have a yield of 50 cfs. The augmented flows would serve the dual purposes of water supply and stream quality maintenance. Studies made by the Tulsa District Office, Corps of Engineers, indicate that the most reasonable alternative would be a system of three dams, located at the same sites as the proposed Corps projects at Council Grove, Marion, and Cedar Point. It is estimated by the Corps that such a system could be built for a total cost of about $17,680,000. Corresponding annual costs would be $688,000, equivalent to amortization over a period of 50 years with interest at 3 per cent.

In summary, the annual benefits of providing the recommended flow rates, totalling 50 cfs at Emporia, are considered to be $688,000, exclusive of operation and maintenance costs. This is an aggregate benefit which might be distributed, as appropriate, to the several storage projects used to accomplish the purpose.

Distribution of Annual Benefits

Dividing the gross annual benefit of $688,000, by the recommended total flow of 50 cfs at Emporia, gives a unit value for upstream storage of $13,760 per cfs of yield. By applying this unit value, the questions posed in the Introduction may be answered as follows:

1. The monetary benefit from storage to maintain 10 cfs on the Neosho at Emporia is $137,600 per year.
2. The monetary benefit from storage to maintain 40 cfs on the Cottonwood at Emporia is $550,400 per year.
3. If storage on the Cottonwood is limited to an amount which will assure only 17 cfs at Emporia, then its monetary benefit may be taken as seventeen-fortieths of the above amount, that is, $233,900 per year. Attention is again invited to the desirability of providing, somewhere upstream from Emporia, sufficient storage to yield a total of 50 cfs.
4. Since the full accomplishment of the desired objectives requires that storage be located upstream from Emporia, no monetary benefits would accrue to the John Redmond Dam, if upstream storage is provided to yield the full 50-cfs rate at Emporia.
5. If the Curtailed Plan is followed (firm flow of 27 cfs at Emporia), then storage at John Redmond would have value, in that its increase of the minimum stream flow would permit a greater development at downstream com-

munities even though Emporia's growth was restricted. Therefore, in the Curtailed Plan, suggested benefits for John Redmond are $151,400 per year. This figure is equal to the aforementioned unit value ($13,760 per cfs) times the increase of 11 cfs (i.e., from 27 to 38 cfs).

EXHIBIT A-1

Oxygen Balance Calculations
Average Conditions - 2015 A. D.

Data and Assumptions

1. Water Temperature: 77°F = 25°C.

2. M & I Water

   a. Gross takeout - projected average annual.

   b. Return flow - 50% of gross takeout.

3. Waste Loads: 10% projected P.E.'s - see Table 1.

4. Time of Travel in Stream: 15 mi./day.

5. For Oxygen Sag Equation:

   a. 20°C; $k_1 = 0.1$; $k_2 = 0.2$; $f = 2.0$

   b. 77°F; $k_1 = 0.126$; $k_2 = 0.216$; $f = 1.72$

6. River Flows: Entering Emporia - 50 cfs
   Leaving John Redmond Dam - 38 cfs

7. Channel Loss of Water - assumed to be offset by natural inflows.

Summary of Calculations

Point	River Flow cfs	M & I Takeout cfs	Waste Flow cfs	Dissolved Oxygen in River (ppm)
Above Emporia	50.0			7.1 (assumed)
At Emporia	43.9	12.2	6.1	
Critical Point Below Emporia	---			6.1
Leaving John Redmond Dam	38.0*			7.1 (assumed)
At Burlington	36.78	1.22	0.61	
	37.39			7.0
At Leroy	37.19	0.20	0.10	
	37.29			
At Iola	32.35	4.94	2.47	
	34.82			6.9
At Humboldt	33.46	1.36	0.68	
	34.14			
At Chanute	26.48	7.66	3.83	
	30.31			6.0
Critical Point Below Chanute	30.31			5.6

*Re-regulation at John Redmond Reservoir.

EXHIBIT A-2

Oxygen Balance Calculations
Seasonal Conditions - Summer Month, 2015

Data and Assumptions

1. Water Temperature: 86°F = 30°C.

2. M & I Water

   a. Gross takeout - 1.5 times average annual.

   b. Return flow - 1/3 of gross takeout, i.e., same as average return flow.

3. Waste Loads - same as for average conditions.

4. Time of Travel - same as for average conditions.

5. Oxygen Equation: $k_1 = 0.158$; $k_2 = 0.232$; f - 1.47

6. River Flows: Entering Emporia - 75 cfs
   Leaving John Redmond Dam - 57 cfs

7. Channel Loss of Water - assumed to be offset by local natural inflows.

Results

Repeating the calculation procedure followed for average conditions, minimum D. O. content at critical points are:

Below Emporia - 5.6 ppm

Below Chanute - 5.6 ppm

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